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Delineating the geographic context of physical activities: A systematic search and scoping review of the methodological approaches used in social ecological research over two decades

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ABSTRACT

Background: The social ecological approach suggests that the spatial context among other factors influence physical activity behavior. Ample research documents physical environmental effects on physical activity. Yet, to date inconsistent associations remain, which might be explained by conceptual and methodological challenges in measuring the spatial dimensions of health behavior. We review methods applied to measure the spatial contexts in the social ecological physical activity literature.
Methods: Online databases and selected reviews were used to identify papers published between 1990 and 2020. A total of 2167 records were retrieved, from which 412 studies that used physical activity as a primary outcome variable, included measures of the physical environment and applied the main principles of the social ecological approach, were included.
Results: Subjective approaches were the dominant method to capture the spatial context of physical activities. These approaches were applied in 67% (n=279) of the studies. From the objective approaches an administrative unit was most prevalent and was applied in 29% (n=118) of the studies. The most comprehensive objective spatial methods that capture the true environmental exposure, were used only in 2% (n=10) of the studies.
Conclusions: Current social ecological physical activity research applies simple conceptualizations and methods of the spatial context. While conceptual and methodological concerns have been repeatedly expressed, no substantive progress has been made in the use of spatial approaches. To further our understanding on place effects on health, future studies should carefully consider the choice of spatial approaches, and their effect on study results.

1. Introduction

1.1. Background

The value of multilevel research and intervention approaches in health promotion is well recognized, with some stating that interventions are most effective when conducted at various ecological levels (Richard et al., 2011; Sallis et al., 2006). Consequently, social ecological approaches have become increasingly applied in the field of health promotion during the past few decades (Golden and Earp, 2012; Richard et al., 2011; Sallis and Owen, 2015). Social ecological approaches focus on the multiple levels of factors that can influence human health behavior, including physical, sociocultural, policy and information environments, as well as individuals' personal biological, psychological and sociodemographic factors (Green et al., 1996; Richard et al., 2011; Sallis and Owen, 2015; Stokols, 1992). The physical environment

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is of particular importance when applying a social ecological lens to population health promotion due to its wide-reach and focus on the context of behaviours rather than individual characteristics (Golden and Earp, 2012; Sallis et al., 2006; Sallis and Owen, 2002).

Social ecological approaches are described in the literature with multiple, interchangeable labels, such as ecological perspective, social-ecological model, social ecological approaches, ecological model(s), and multiple-level models (Richard et al., 2011). Despite these minor terminological and conceptual differences, common to all social ecological approaches of human health behavior is that they evolved from the fields of social ecology, environmental psychology and social and public health sciences. Most of these approaches arose from the seminal works of Kurt Lewin (1951) Roger Barker (1968), Urie Bronfrenbenner (1979) as well as the research and theorizing of social ecology by Daniel Stokols (1992, 1996).

1.2. The physical environment in social ecological physical activity research: state of science and limitations

Social ecological models have been widely applied to understand determinants of health behaviors, including physical activity (De Vries, Bakker, Van Mechelen and Hopman-Rock, 2007; Saelens and Handy, 2008; Sallis et al., 2016), nutrition (Robinson, 2008), and sedentary behavior (Frank et al., 2007; Koohsari et al., 2015). Social ecological approaches sit particularly well with the field of physical activity research because differing physical activities are context-dependent and occur in certain physical environmental settings (Sallis and Owen, 2015; Stokols, 1996, 2018).

Interest in understanding the associations between physical environments and physical activity using social ecological principles has accelerated during the past decade (Sallis and Owen, 2015). A wide range of research has shown that physical environmental factors such as mixed land uses, street connectivity, accessibility, residential density, quality of traffic environment, nature, and green spaces are associated with various types of physical activity behavior (Giles-Corti et al., 2016; Kerr et al., 2012).

However, overall, the body of evidence remains inconsistent. Multiple studies have found that green spaces and parks are associated with physical activity (Eronen et al., 2013; Sallis et al., 2016; Thornton et al., 2016), yet others report negative associations between the presence of neighborhood parks and physical activity (Borst et al., 2009; Chaudhury et al., 2016). Land-use mix is frequently positively associated with physical activity (Frank et al., 2010; Saelens and Handy, 2008), yet in a large international comparison study mixed land-use was not associated with adults' physical activity (Sallis et al., 2016).

Differentiating physical activity by domains, such as transport, leisure-time, or total physical activity, has been discussed as a potential solution to overcome discrepancies in results (Notthoff et al., 2017; Saelens and Handy, 2008; Van Cauwenberg et al., 2011). Besides differentiating between the types of physical activities, multiple studies have concluded that the inconsistent results are potentially due to the methodological, analytical, and measurement challenges related to capturing physical environmental characteristics and the spatial context of physical activities (Kajosaari and Laatikainen, 2020; Kwan, 2012; Saelens and Handy, 2008; Van Cauwenberg et al., 2011; Zhao et al., 2018).

According to Sallis and Owen (2015), studies adopting the principles of social ecological models have had considerable methodological challenges trying to understand complex interactions between individual factors and the physical environment. One important issue for consideration is how the individual-level spatial information is treated in relation to the spatial environmental data (Jia et al., 2020). Previous studies have mainly used estimates of people's residential neighborhood environments, assuming equal exposure and use for all residents, and thus overlooking people's true mobility behavior and exposure (Hasanzadeh et al., 2017; Perchoux et al., 2013). Moreover, a number of studies interested in the "neighborhood effect" on human health define the spatial context by asking residents what they like or dislike about their neighborhoods, instead of measuring the actual nature of people's transactions with their environments (Talen and Shah, 2007).

Self-reported and subjective measures of the spatial context of physical activities often rely on respondents' self-defined "neighborhood" or define neighborhoods using an estimated walking duration from home (Ding et al., 2013; Saelens and Handy, 2008). Moreover, differences exist in measurement of perceived built environment variables to study environmental associations with physical activity. Many studies ask the respondents to define the environmental characteristics, for instance asking respondents to describe the main type of housing in their neighborhood which is then used as a proxy measure for residential density (Ding et al., 2013; Shigematsu et al., 2009). However, studying health behavior disconnected from the actual spatial context is not optimal, as health behaviors take place in specific locations which are characterized by various environmental features.

Besides these subjective approaches, many studies measure physical environment characteristics and the spatial context objectively. Objective measures of the physical environment are most often derived from geospatial data sources, such as national or international census statistics, land use, land cover and remote sensing databases, observation data, and other possible surveys (Adams et al., 2014; Lee et al., 2017). Studies applying objective measures may use administrative units, home location, or a single buffer-based boundary (typically around home) to define the spatial context of physical activity (Frank et al., 2017; Yen et al., 2009). However, these approaches tend to assume that residents of the same area are exposed to the same neighborhood characteristics that can have an effect on their physical activity behavior. While these studies enable an objective analysis of the physical environment, they are not without limitations and concerns about their validity have been raised (Pearce, 2018). In most cases the applied objective approaches tend to assume that individuals are exposed solely to the environment around their residence and, consequently, do not capture the context outside the applied neighborhood boundaries (Hasanzadeh et al., 2017; Laatikainen et al., 2018; Perchoux et al., 2016).

The modifiable areal unit problem (MAUP) and the Uncertain Geographic Context Problem (UGCoP), on the other hand, exemplify the challenges involved in objectively measuring the physical environmental effects on physical activity (Kwan, 2012; Openshaw, 1981). While both deal with the challenges in capturing the spatial context of human (health) behavior, the MAUP is linked to the problems in capturing the areal unit of analysis at differing spatial scales or with varying criteria (Clark and Scott, 2014). The UGCoP describes the uncertainty of the researcher-defined unit of analysis in capturing the spatio-temporal realities of actual human behavior (Kwan, 2012). An individual's true "activity space" might differ in reality a lot from the pre-defined home buffers (e.g., 500 m around home) or administrative areas (Holliday et al., 2017). People are most likely exposed to various different environments beyond their home surroundings when conducting different physical activities (Kajosaari and Laatikainen, 2020; Zhao et al., 2018).

Thus, there are multiple ways to define the spatial context of human health behavior and capturing the spatial context where the health behavior actually takes place is not straightforward. Yet, there exists no comprehensive understanding of how the spatial context is measured and treated in research interested in physical environmental effects on physical activity.

In their review Macintyre et al. (2002) concluded that instead of there being one single, universal "area effect on health" there appear to be several area effects on certain health outcomes, that may have different associations with various population groups, and in different types of areas. A recent review on the association of objective and perceived measures of the neighborhood environment and physical activity in older adults concluded that there is an evident need for validated objective and perceived geographic scales which could improve

the comparability of findings in physical activity research (Peters et al., 2020). Moreover, another recent review on children's physical activity geographies revealed that the reporting of spatial methods was inconsistent across studies and in some cases even incomplete (Smith et al., 2021).

1.3. Review aims

With the increasing interest towards the social ecological approach of health behavior, the nature of people's transactions with their environments, and how the physical environment associates with individuals' physical activity behavior (Golden and Earp, 2012; Richard et al., 2011; Sallis and Owen, 2015), there is an evident need to systematically search and analyze how the spatial context is being captured in these studies. The results regarding the associations between physical environment characteristics and physical activity remain inconsistent, which may be a result of various methodological and measurement challenges related to capturing the spatial context and different domains of physical activities (Annear et al., 2014; Kwan, 2012; Notthoff et al., 2017; Peters et al., 2020; Saelens and Handy, 2008; Smith et al., 2021; Zhao et al., 2018). Thus, this scoping review presents a valuable opportunity to conduct an extensive literature search from diverse sources to characterize the quantity and quality of the literature using a social ecological approach to capture the spatial context of physical activities. Moreover, this review offers an opportunity to identify the main concepts, methods and knowledge gaps related to the usage of different spatial approaches in studies applying social ecological approaches (Grant and Booth, 2009).

Sallis and Owen (2015) who have introduced the widely applied ecological model of physical activity, have suggested that research applying ecological models could benefit from a profound theoretical and methodological scrutiny to create more comprehensive study settings. Moreover, there tends to exist a general consensus in the health-place research field that the main methods applied are limited to administrative units and/or home buffers (Hasanzadeh et al., 2018; Pearce, 2018). However, no systematic analysis exists on the methodological approaches applied. Hence, this review was conducted to systematically map the literature to identify the nature and extent of research methods and approaches applied to capture the spatial context of physical activities. Thus, the aim of this scoping review is to identify how the spatial context has been conceptualized and measured in studies applying the social ecological approach in physical activity research. The objectives of this scoping review were to: (1) systematically search and identify the research undertaken in this area and (2) create a comprehensive overview of the applied spatial methods for future research and reviews to build on. Thus, the following research question was formulated for this review: What is known from the literature about the conceptual and methodological aspects of capturing the spatial context and multiple dimensions of the social ecological approach in physical activity research?

2. Methods

This paper presents a systematic search and a scoping review on how the spatial context and physical environment is being captured in studies applying social ecological approach to study physical activity. The review followed the PRISMA Extension for Scoping Reviews (PRISMA-ScR) framework. A protocol for this scoping review was drafted by an information specialist and revised by the research team taking part in the screening phase. The original protocol was drafted in Finnish due to all authors conducting screening being Finnish speaking. An English translation of the protocol and all appendices of this review have been uploaded into Zenodo (10.5281/zenodo.5184745).

2.1. Eligibility and inclusion criteria

Included papers needed to measure or focus on the effects of the physical environment on physical activity and employ a social ecological approach (Richard et al., 2011; Sallis et al., 2006). Peer-reviewed journal papers were included if they investigated the association between physical environments and any kind of human physical activity, followed the social ecological approach, and were written in English. Quantitative, qualitative, and mixed-method studies were included in order to consider different aspects of measuring the physical environment. Papers were excluded if they focused only on indoor space or did not measure the physical environment, did not have human physical activity as an outcome variable, or did not follow the principles of the ecological framework in terms of aiming at a multiple level approach. Study protocols, books, book chapters, commentaries, dissertations, editorials, theoretical and review papers were also excluded from the review. The detailed eligibility criteria can be found in Appendix 1.

The keyword selection was based on the expertise of the authors, the manual screening of eligible studies, reference lists of previous reviews on social ecological approaches and on capturing the relevant keywords from the preliminary searches run in Scopus. The search strategies and procedures were drafted by an experienced information specialist [MaS] together with the research team and further refined through discussion. To collect the literature, we used three online search rounds and a bibliography of four review articles and one book chapter on social ecological approaches (Golden and Earp, 2012; Richard et al., 2011; Richard et al., 1996; Roux, 2007; Sallis and Owen, 2015). The search strategies were tested in the preliminary searches performed in the Scopus database and refined through an iterative process. The final search strategies were conducted for Scopus, Web of Science (WoS) and PubMed databases. In the first round the keywords consisted of the terms and synonyms for "physical activity", "physical/spatial environment" and "social ecological approach" which were then combined with Boolean operators and in the third round also the proximity operator was utilized. The search results were exported into Excel, and duplicates were removed by the information specialist. The final search strategies, procedure and syntaxes are presented in Appendix 2. Searches were undertaken between October 2019 and July 2020. During searches no restrictions on language or time were applied. The literature searches were conducted by the information specialist.

2.2. Screening strategy and data charting

Five authors (TR, AK, PB, AJP, MK) screened publications independently based on predefined inclusion and exclusion criteria (see Appendix 1 and 4). To increase consistency among the reviewers, authors together with the information specialist first screened 221 papers, discussed the results, and revised the screening criteria and strategy before beginning the final screening for this review. The reviewers identified in the first screening phase that multiple studies do not clearly mention if they truly apply the multilevel social ecological approach in the title, abstract or keywords of their study. This resulted in authors screening the full texts of 1977 potential studies. In an unclear case, all authors consulted at least one other author before making the final decision on inclusion or exclusion.

A data-charting form was developed jointly by the reviewers. Reviewers developed the form and updated it in an iterative process during the planning and screening phase and it was tested by the team before final use. Written instructions on how to record, categorize and code the data were included in the form. There were also illustrations about the different spatial approaches available for each author conducting the review (see Fig. 1). The five reviewers independently charted the data and discussed the results. If one of the reviewers was uncertain about the screening or data extraction, they were instructed to discuss their choices with other authors. Thus, all unclear cases and disagreements were resolved by consensus and discussion with other reviewers. A

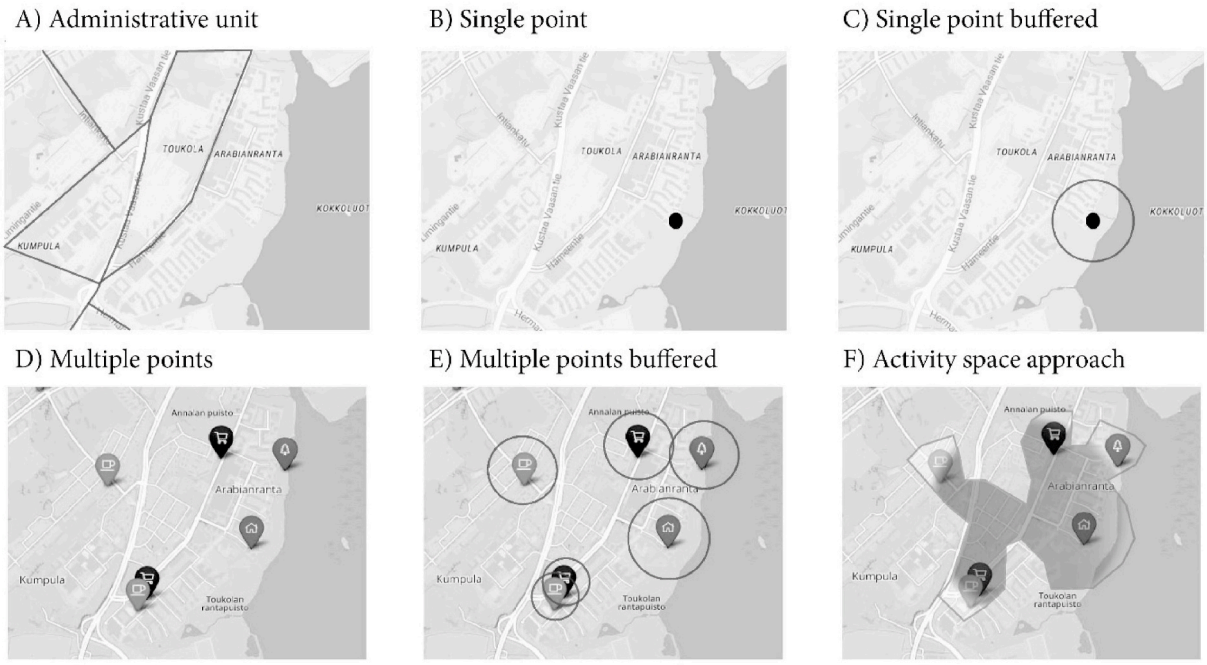

Fig. 1. Different objective measures to capture the spatial context were analyzed in each study. Optionally the study might not have used any of the presented approaches but used only respondents' subjective evaluation to capture the context of physical activities.

duplicate round of data screening and charting was conducted for a random 10% selection of all articles screened by the researchers, resulting in a total of 44 included articles being charted at least by two different researchers.

The final database included information on first author and publication year; location and setting; sample characteristics (sample size, age group); study design; and measures of physical activity (leisure-time, transportation, and any other type of physical activity measured, such as total physical activity). Moreover, measures of different levels of the ecological model of physical activity by Sallis et al. (2006) were included. In their model, Sallis and colleagues suggest that besides the intrapersonal level, the environmental levels include policy (e.g., land-use policies, transportation regulations, health programs), information (e.g., healthcare counseling, advertising), socio-cultural (e.g., peer support, societal norms, crime), natural (e.g. weather), and perceived environments (e.g., perceptions of safety). It must be noted that Sallis and colleagues (Sallis et al., 2006; Sallis and Owen, 2015) refer to the concept of behavior setting as places where physical activity may occur as one of the levels of their model which we operationalized as physical environment level for this review. Finally, also the operationalization of the spatial context was included in the database. In the process of data-charting, the subjective spatial context was coded as subjective context and the objective spatial context was coded as either administrative unit (A), single point location (B), single point buffered (C), multiple points (D), multiple points buffered (E), or activity space approaches (F) (Fig. 1). This categorization was based on authors expertise and previous research on capturing the environmental exposure and spatial context of health behavior (Hasanzadeh et al., 2017, 2018; Kestens et al., 2018; Perchoux et al., 2013, 2016).

The studies included were grouped by the approach used to operationalize the physical environment context. Thereafter studies were summarized by the type of research, different ecological model levels analyzed, their periodic distribution, and the physical activity measures used. Appendix 3 provides all extracted information for the included studies.

3. Results

After removing the duplicates, a total of 2167 articles were identified from the introduced searches of electronic databases and selected review articles and one book chapter list of references. Based on the title, the abstract and the introduction, 190 articles were excluded. From the remaining 1977 studies, 1565 were excluded after full-text assessment for the following reasons: 392 did not measure physical environmental features, 667 did not directly study human physical activity as an outcome, 464 were not considered to be original quantitative or qualitative research (e.g., were review articles, commentaries, book chapters, editorials, protocols, conference posters), 41 were written in a language other language than English, and one study was excluded because it was not possible to retrieve. The main reason for exclusion of full texts were recorded and are provided in Appendix 4. The remaining 412 studies were considered eligible for this review (Fig. 2). The study characteristics are presented in Table 1.

3.1. Methods used to measure the spatial context

From the 412 analyzed studies 345 (84%) used only a single method to capture the spatial context. Overall, 12% (n=61) used two different methods and 1% (n=6) used three different methods. None of the studies used more than three different approaches. Detailed information about the spatial context measures used in each study included in this review are presented in Appendix 3.

The subjective approach to capture the spatial context was applied in 276 (67%) of the studies and different objective approaches in 209 (51%) of the included studies (Fig. 3). Almost a third (29%) of the studies used administrative units and a tenth (10%) used a single buffered point approach to capture the spatial context of physical activities. Single and multiple point locations without applying buffers around the points were used only in 3% and 5% of the studies, respectively. Buffering multiple points to capture the physical environmental context was used only in 2% of the studies. Similarly, activity space approaches were used only in 2% of all the studies analyzed.

We further analyzed the spatial context in different studies using the number of levels of the ecological model each study applied. Studies

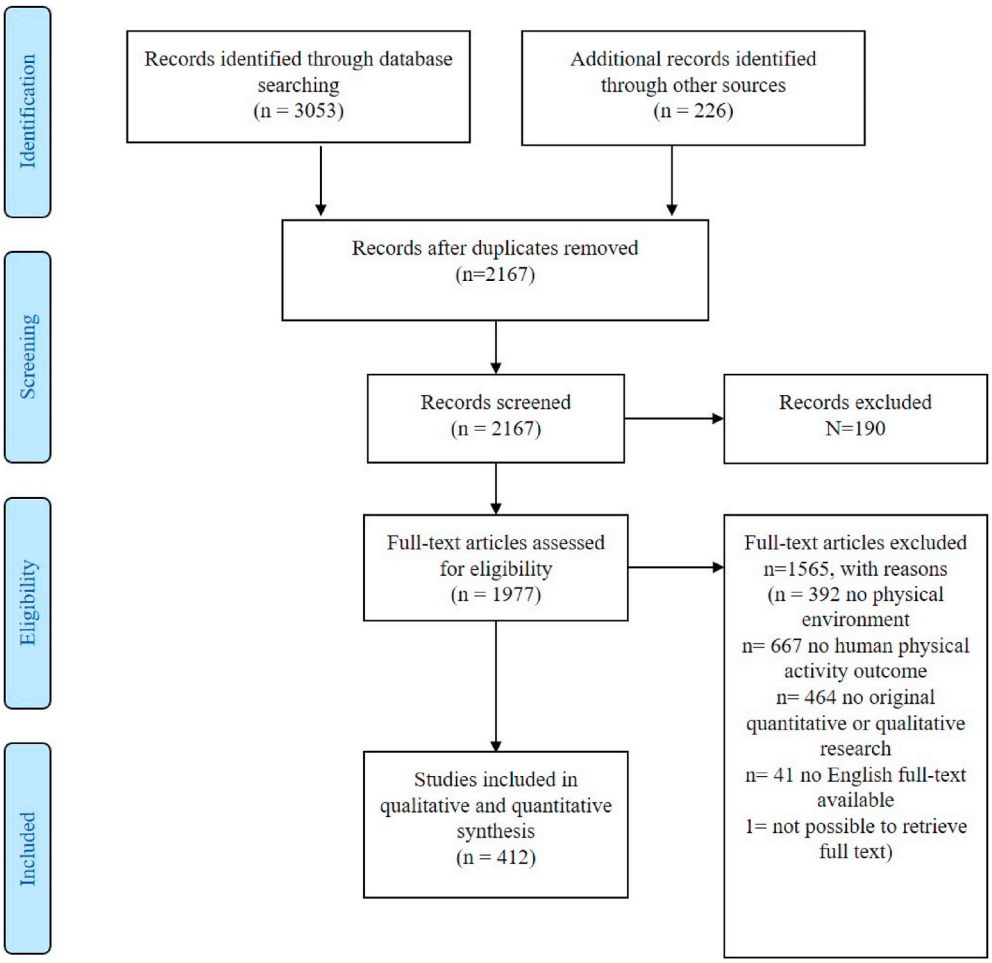

Fig. 2. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for studies identified, screened, and included in the review.

using subjective approaches to capture the spatial context were mostly those that applied measures from three (n=140, 51%) or four (n=57, 21%) different levels of the ecological model (Fig. 4). Administrative units were mostly used in studies applying measures from two (38%) or three (41%) different ecological levels. Single point locations were rarely used (11 studies), but those that did apply single points were dominantly studies with measures from four different ecological levels (45%). Single buffered points were most common in studies that applied measures from three different ecological levels (58%). Both multiple point approaches (points or buffered points) were used in studies that applied measures from four different levels at most. Those studies that applied activity space approaches (10 studies) were predominantly (70%) studies that applied measures from one additional level besides the physical environment.

Looking more closely how the spatial context has been applied in studies combining different levels of the ecological model it is evident that the more levels included, the less objective spatial approaches are being used (Fig. 5). Most of the studies combined two distinct levels with the physical environment level (n=189) and subjective approaches were used in 60% (n=140) of these studies. In these studies, the most common objective method applied was an administrative unit (21%) and point approaches were used in 15% of these studies. Overall, 69% of the studies that applied measures from one level in addition to the physical environment used objective approaches. In this category, administrative unit was the most common method used to capture the spatial context (38%) and different point methods were used in 25% of these studies. When comparing these results to the studies that combined measures from two additional levels with the physical environment it is evident that more and diverse objective approaches were used when only measures from two levels were applied.

We also analyzed the periodic distribution of the spatial approaches of each study in five-year intervals. The periodic distribution (Fig. 6) showcases the dominance of the subjective approaches in the field over time. Of the objective approaches the administrative unit has been most consistently applied over time, yet it seems that its usage has not grown much during the past 10 years. Other objective approaches have been applied since around 2005 but their usage has also not become more common in recent years.

Finally, the use of the different spatial methods used with different physical activity outcome measures (transport physical activity, leisure-time physical activity and any other type of physical activity) was analyzed (Table 2). All potential physical activity outcomes were recorded; thus, a single study could have measured one or more different outcome categories. There were 119 studies that explicitly measured leisure-time physical activity, 117 that reported focusing on transportation physical activity and 329 studies measured physical activity as any kind of mixed or summary measure (for example as total physical activity).

More studies used objective (n=65) than subjective (n=52) methods to capture the spatial context of transportation physical activity and almost an equal amount of objective (n=56) and subjective (n=63) approaches were used to capture the spatial context in studies looking specifically into leisure-time physical activity behavior. Studies that measured physical activity as an outcome in any other way were dominantly capturing the physical context using subjective methods (n=197) compared to objective methods (n=132).

Table 1
Characteristics of the included 412 studies.

Characteristics of the included studies	Number of individual studies (N)
Study Region	*N*
North America (US, Canada)	197
Europe (Continental Europe, UK, Greenland)	90
Asia (Asian continent, Middle East, Arabian peninsula)	36
Australia, New Zealand	64
South America	5
Africa	6
Multiple countries	14
Study setting	*N*
Urban	167
Mixed	164
Rural	37
Not specified	44
Study desing	*N*
Cross-sectional	352
Longitudinal	60
Type of research	*N*
Quantitative	317
Qualitative	75
Mixed	20
Type of physical activity measured	*N*
Recreational/leisure-time physical activity	119
Transportation physical activity	117
Any other mix of physical activity	329
Participant age group	*N*
Children, Adolescents	99
Young adults, Adults	199
Older adults	57
Many age groups	46
Not specified	11
Year of publication	*N*
Before 2000	1
2000–2004	24
2005–2009	55
2010–2014	135
2015–2019	185
2020-	12
Sample size	*N*
<100	95
100–299	66
300–499	52
500–999	63
≥1000	112
No individual or not specified	24

4. Discussion

The aim of this scoping review was to systematically map the literature to identify the nature and extent of research methods and approaches applied to capture the spatial context of physical activity. Overall, our approach allowed us to identify key trends and gaps in research applying the principles of social ecological models to measure associations between the physical environment and physical activity.

There were 412 articles included in this review, which were predominantly conducted in North America (US, Canada) and in urbanized settings, focusing on adult populations, and using quantitative research approaches and cross-sectional study designs. Most of the articles were conducted after 2010 with the highest number of articles published between 2015 and 2019.

Subjective approaches (such as the Neighborhood Environment Walkability Scale; NEWS) were dominant methods used to conceptualize the spatial extent of physical activities. Thus, most of the studies asked the respondents to define their neighborhood context or applied a researcher-based definition of a neighborhood by for example describing it as an area within a certain time or distance-based walking measure from home. There are multiple examples of the NEWS and other widely applied and validated subjective neighborhood environment measurement scales (Adams et al., 2009; Cerin et al., 2009; Cerin et al., 2006). Such measures have considerable utility in environmental health research due to their relatively low implementation costs and straightforward data cleaning and analytical approaches. However, these approaches remain limited in capturing the spatial contexts of physical activity behavior beyond home surroundings as well as the activity spaces and true physical environmental exposure of physical activities. Moreover, besides subjective descriptions of the spatial context these approaches often rely on subjective description of specific physical environment features. For future research, it is essential that researchers take these issues into account when choosing measures and methods and when interpreting study results. For example, while a recent study showed associations between subjective and objective measures of the environment with physical, social and mental health outcomes, stronger evidence was found for associations between physical health with objectively assessed neighborhood environments compared with subjectively assessed neighborhood environments (Zhang et al., 2019). Moreover, while for example biodiversity is in general a positive and eligible aspect, a Swedish study showed recreational preferences of their study participants being negatively related to high biodiversity value (Qiu et al., 2013). Gobster, Nassauer, Daniel and Fry (2007) have concluded that people tend to have a limited capacity to perceive objective measures of the urban natural environment correctly. Sugiyama et al. (2008) showed in an Australian study that people who perceived their neighborhoods highly green were more likely to have better physical and mental health than those who perceived the lowest greenness of their neighborhoods. Moreover, a review by Orstad et al. (2017) concluded that perceived and objective neighborhood environmental measures are related but distinct constructs that account for unique variance in physical activity. Notions of the potential mismatch between people's perceptions and preferences and the reality of the environmental features warrant careful considerations on objective/-subjective assessment of neighborhoods, environmental measures, and estimated versus actualized delineations of the exposure. These issues are particularly important to recognize if recommendations about the health promoting environmental features for policy and practice are given based on perceived assessments of the neighborhoods and their physical features.

Many studies included in this review applied objective approaches to capture the spatial context of physical activities. The most prevalent objective approach was an administrative unit (e.g., census tract or a postal/zip code area) which was used in almost a third of the studies. These are typically easily available and can be combined with other data aggregated on the same level, which may explain their popularity. However, delineating the spatial context of physical activities through an administrative unit is unlikely to represent individuals' neighborhood or activity spaces accurately. The second most often used method was the single point buffer approach which was applied in a tenth of the studies. It can be argued that the single buffered point approach is more precise in capturing the immediate home neighborhood surroundings of an individual compared to the administrative unit that is based on arbitrary administrative boundaries (Hasanzadeh et al., 2017). However, while the environmental characteristics of the home surroundings arguably plays a role in everyday physical activity behavior (Adams et al., 2009; Frank et al., 2017), it provides only a partial picture about the environmental exposure and spatial contextual effects on physical activity (Kajosaari and Laatikainen, 2020; Perchoux et al., 2013).

Multiple points, multiple points buffered, and activity space approaches, that are individual-based delineations of areas and places of everyday activities, were used rarely, in 5%, 2%, and 2% of studies included in this review, respectively. Thus, objective methods that can capture the environmental exposure and the spatial context of physical activities remain rare in studies applying the principles of social ecological models in physical activity research. This is evident also when looking into the periodic distribution of the spatial methods used in the studies included in this review. The periodic distribution showed that the spatial aspects in ecological physical activity research has gained

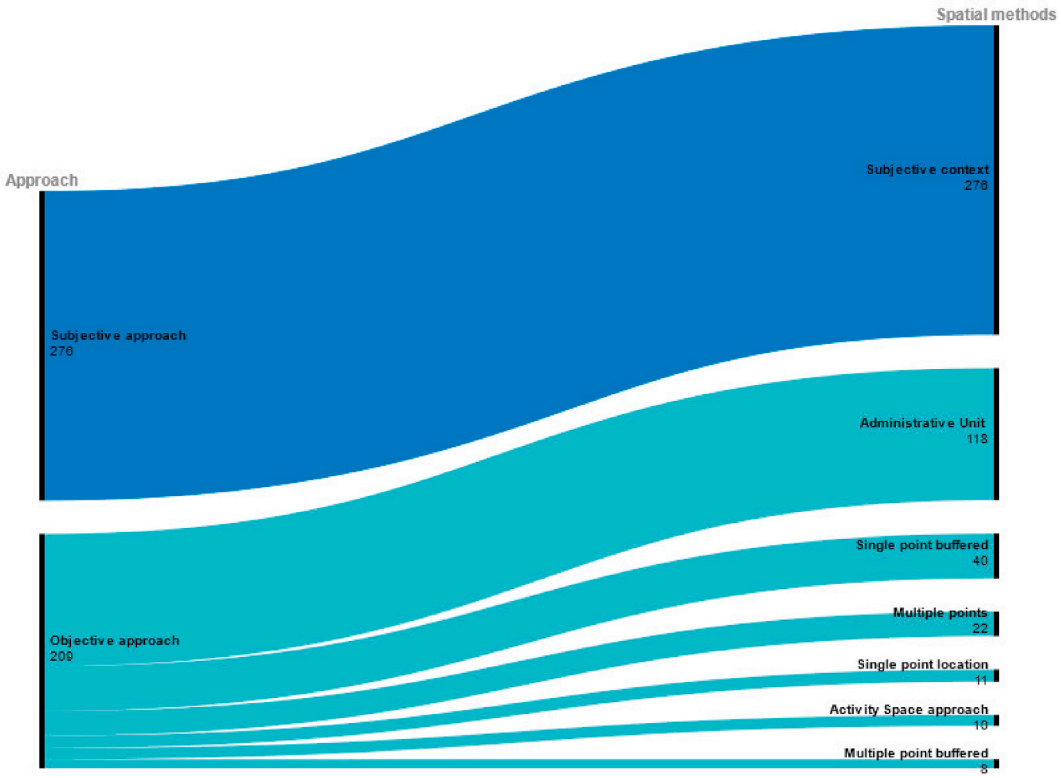

Fig. 3. Studies by the primary method used to capture the spatial context.

popularity over the years as the total number of studies has continuously increased. Similarly, the use of subjective approaches has been increasing whereas the use of objective approaches to capture the spatial context in these studies has remained mostly the same, except for the use of administrative units which has grown in prevalence over time. Limitations in geospatial data and methodological availability and expertise, and associated increased project costs could explain partly these low numbers.

In regard to how the spatial context has been measured in studies focusing on different physical activity outcomes, it seems that studies that focus on transportation physical activity more frequently apply objective approaches compared with studies that focus on other physical activity outcomes. Subjective approaches were applied in the majority of the studies that measured leisure-time physical activity, whereas less than half of the studies that focused specifically on transportation physical activity applied subjective approaches. In studies that did not directly specify the outcome as transportation and leisure-time physical activity the subjective approach was clearly the most dominant method to capture the spatial context of physical activity behavior. This finding could also be due to varying expertise related to geospatial issues in different research fields, as the roots of physical environment-physical activity research reaches towards the fields of both transportation and epidemiological research (Sallis et al., 2006).

Previous studies have concluded that the spatial approach employed affects associations found between the physical environment and physical activity behavior (Howell et al., 2017; Laatikainen et al., 2018; Zhao et al., 2018). Zenk et al. (2011) found that environmental features were related to weight-related behaviors when they used modeled activity spaces as units of analysis, but the physical environmental features of simple residential neighborhoods were not associated with physical activity. Moreover, Hillsdon et al. (2015) reported that conventional neighborhood delineations do not properly capture the environmental influences of physical activity as 60% of outdoors physical activity of their study participants took place beyond 800m from the residential address. Laatikainen et al. (2018) found green spaces positively associated with older adults' perceived health when the spatial context was measured with an activity space model that takes into account the environmental exposure, but negatively associated when the spatial context was assessed with administrative units.

Objective, measurable location-specific approaches, such as activity space approaches, could tackle the inconsistent results found between the physical environment and physical activity behavior. Linking people's health behavior data to actual locations where the behavior takes place would allow for better comparisons between different studies. Moreover, applying geospatial approaches that can capture environmental exposures offer solutions to the MAUP and the UGCoP which pose central challenges to researchers interested in spatial effects on human health behavior. Moreover, Kwan (2018) has suggested that research that is interested in the neighborhood effect on human (health) behavior urgently needs to move beyond notions of contextual influences that rely solely to specific fixed locations such as home, close to home neighborhood, or workplace, towards assessing people's true environmental exposures. Similar notions about the importance of capturing the actual spatial contexts of physical activities and people's true activity spaces have also been made elsewhere (Kajosaari and Laatikainen, 2020; Laatikainen et al., 2018; Perchoux et al., 2013; Zhang et al., 2019; Zhao et al., 2018).

With the development of research technologies and measurement devices there are multiple geospatial methods and tools available to capture the spatial context of physical activities beyond simple approaches. Geographic Ecological Momentary Assessment (GEMA) is a method that involves repeated data collection from participants in their natural environments in real time (e.g., via mobile phone applications or mini surveys over a phone) and by using GPS tracks for locating the subject at the time of response (Epstein et al., 2014; Kirchner and Shiffman, 2016; Mennis et al., 2018). Smart phone data could offer detailed and high-resolution space-time data about human mobility and health behavior to mitigate issues around accurate measurement of geographic context, but accessing such data remains difficult for researchers due to questions of data ownership and privacy (Poom et al.,

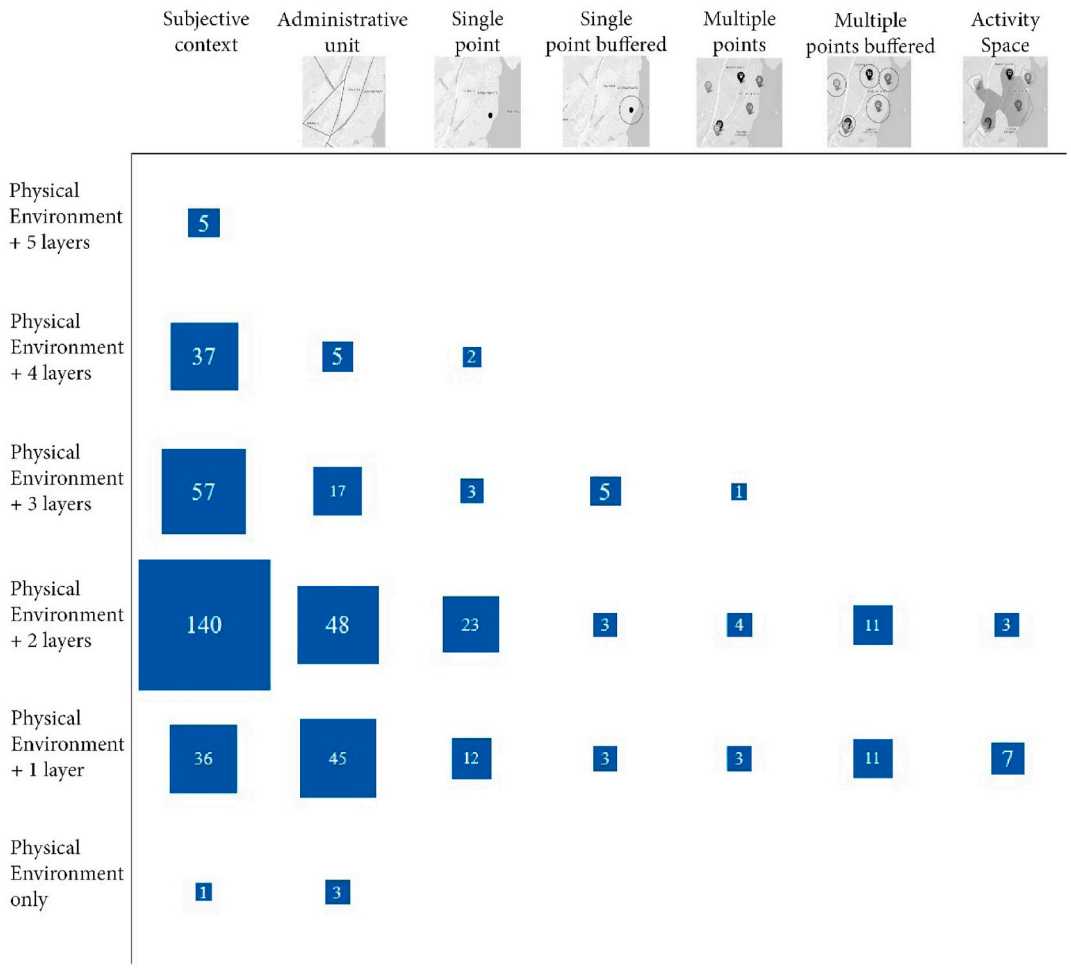

Fig. 4. The spatial context applied in different studies as per the number of different levels each study has applied. The size of the blue box marks the number of studies.

2020; Willberg et al., 2021). Participatory mapping methods (Brown and Kyttä, 2014, 2018; Fagerholm et al., 2016; Gottwald et al., 2016) are examples of cost-effective solutions of location-aware geospatial technologies (Kwan, 2018). Such approaches could be suitable for researchers without extensive spatial or geographical expertise interested in capturing the true spatialities of human health behavior without using too much time, money, and human resources for data collection. Participatory mapping methods offer an alternative to resource heavy GPS in capturing the activity spaces of physical activities (Kestens et al., 2018). Overall, studies that are able to combine both subjective and objective approaches to capture the spatialities of physical activity could offer an optimal solution and the best possible guidance for health promotion research, interventions and policy making (Kwan, 2018; Peters et al., 2020). By combining objective approaches that can capture the true contextual influences with subjective and qualitative information about people's perceptions of the environments, future research could draw together a more comprehensive understanding about the factors associated with human health behavior.

The results of this review also show that studies with a higher number of measured levels of the social ecological approach appeared to employ less comprehensive spatial approaches. Thus, if the study follows the principles of the social ecological approach by including measures from multiple levels it risks failing to address the true spatiality of physical activities. Moreover, in cases where multiple points, multiple points buffered, or activity space approaches were applied, there were most often measures from only two different levels of the ecological model included. In the use of administrative units, there is likely to be a wealth of readily available routine data from multiple measures of the physical, information, and policy environments that is useful to consider. Thus, using administrative units might make it easier to employ a social ecological approach. Moreover, the use of activity space approaches can pose key challenges for researchers without explicit geospatial expertise, even though they offer one of the best possible solutions capturing the environmental exposure (Hasanzadeh et al., 2018; Kwan, 2018). Future research should carefully consider the benefits and challenges in choosing different methods and social ecological approaches for studying environmental associations with physical activity.

A recent review demonstrated that the associations between the physical environment and physical activity vary depending on which measurements of the physical activity and physical environment were applied and observed (Peters et al., 2020). Standardizing reporting and measures of different ecological levels used and creating more comparable spatial methods for the field could help overcoming the issues related to contradictory findings. Another recent review has also called for standardization, transparency, and comparability of the methods used in the field (Smith et al., 2021). With standardized measures of the social ecological approach and spatial methods used in the field, researchers could conduct studies that would be more comparable to each other and more reliable, keeping in mind that the socio-cultural and spatial contexts differ across the globe. In the current situation comparability even between studies from the same geographical region remains challenging because the heterogeneity in spatial methods and measures remain large (Smith et al., 2021). The Spatial Lifecourse

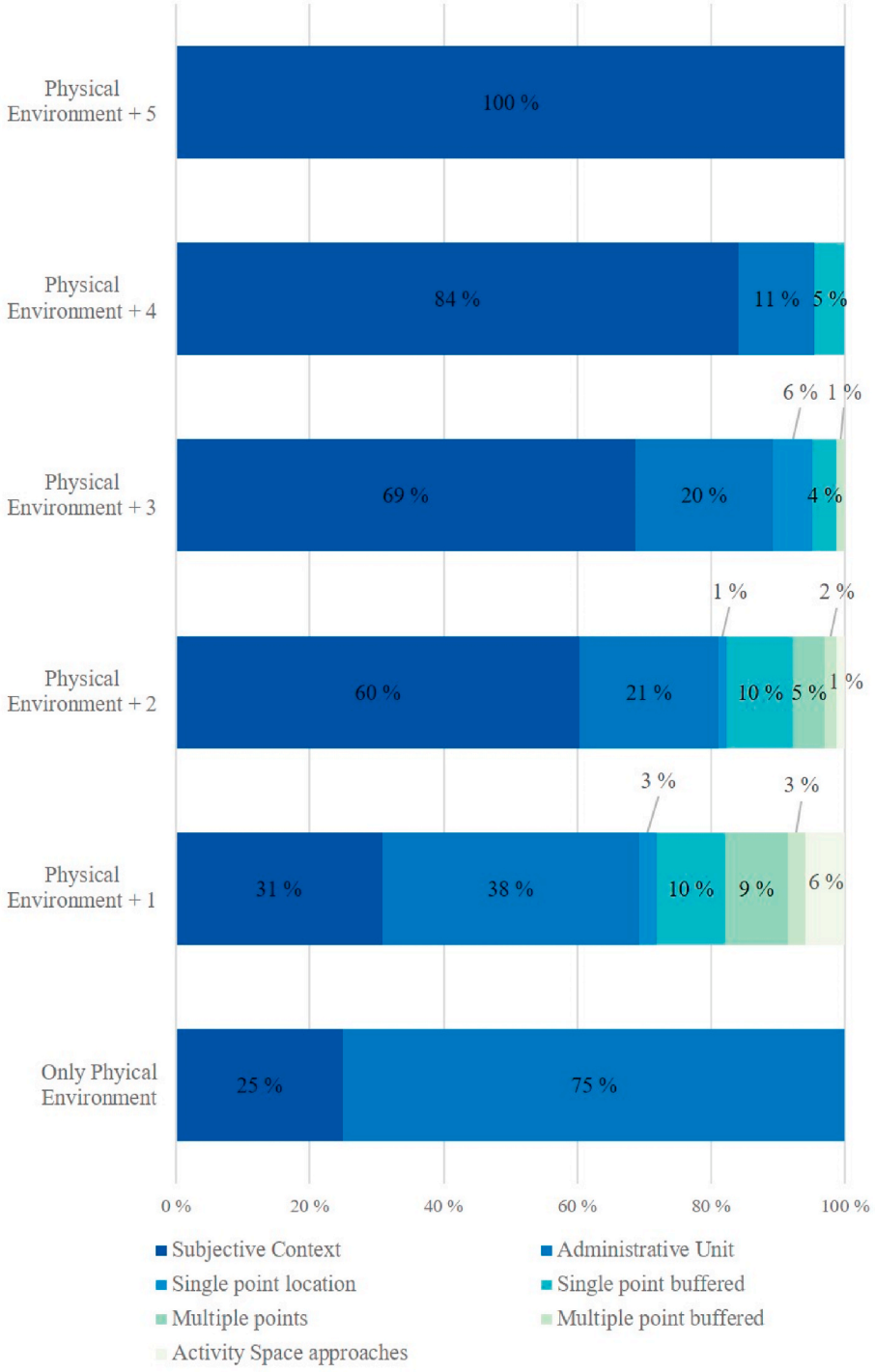

Fig. 5. Number of studies applying different methods to capture the spatial context per different levels of the social ecological approach.

Epidemiology Reporting Standards (ISLE-ReST) statement could be a potential reporting standard for spatial data and methods used (Jia et al., 2020). The increasing availability and applicability of spatio-temporal (big) data opens up many opportunities for environment-health researchers to overcome location-related challenges such as fixed neighborhood locations, the MAUP, the neighborhood effect, and the UGCoP. The increasing call for research on environmental effects on health requires research that can produce detailed and accurate evidence on true spatial exposures influencing human health behavior.

Spatial methods and analytical approaches have developed at speed during recent years and continue to do so with increasing spatio-temporal data accuracy and availability. Yet, the results of this review demonstrate that the advanced approaches which can capture the environmental exposure of physical activities and other health behaviors are still predominantly unused. The remaining challenge is how to close the methodological gap in capturing the geographical context that evidently exists within the wide spectrum of health-place research.

4.1. *Strengths and limitations*

This review is one of the first to systematically map and summarize the methodologies used to capture the physical environmental context

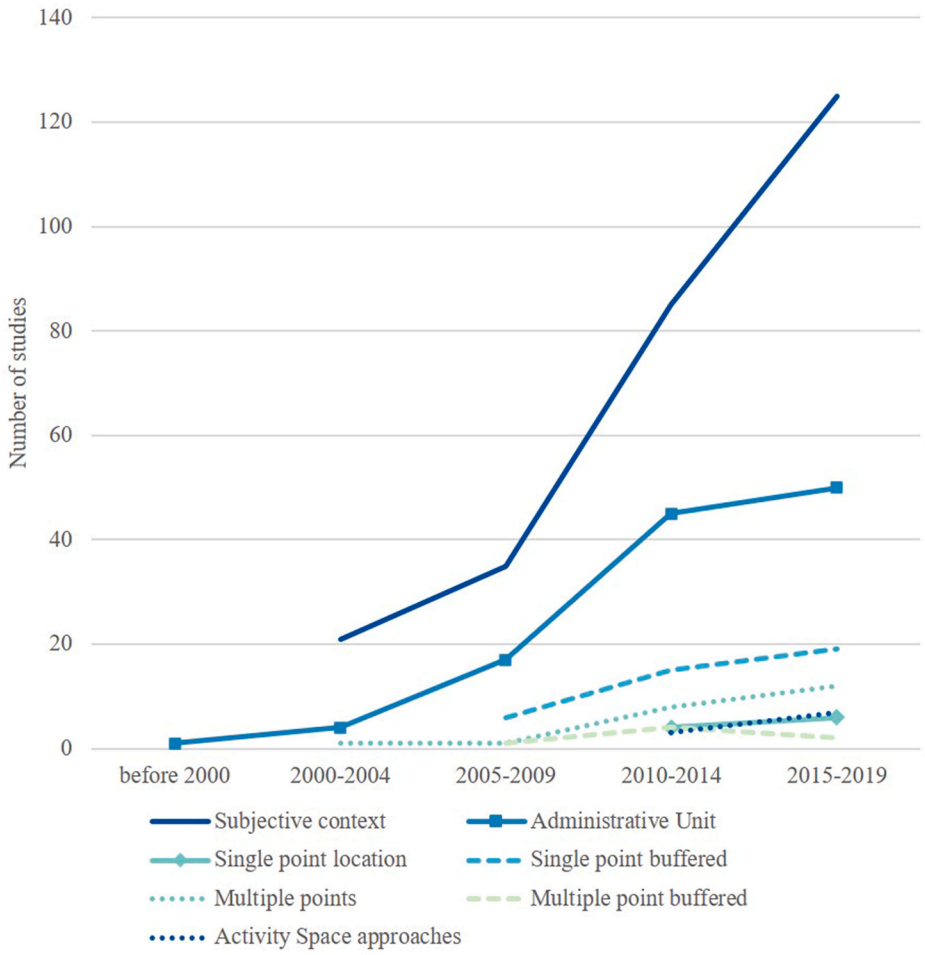

Fig. 6. The periodic distribution of different approaches to capture the spatial context of physical activity.

Table 2
Different methods used to capture the physical context with different physical activity outcomes.

Type of physical activity outcome	Subjective context	Administrative Unit	Single point location	Single point buffered	Multiple points	Multiple point buffered	Activity space approaches	Total
Recreational/leisure-time Physical Activity (n=119)	63 53%	33 28%	3 3%	13 11%	3 3%	4 3%	0 0%	119 100%
Transport Physical Activity (n=117)	52 44%	35 30%	4 3%	14 12%	4 3%	4 3%	4 3%	117 100%
Any other mix of Physical Activity (n=329)	197 60%	76 23%	6 2%	25 8%	16 5%	3 1%	6 2%	329 100%

in studies applying social ecological approaches in physical activity research. While some reviews have also focused on the methods used to capture the geographical and spatial aspects of physical activities, they have exclusively focused on specific age groups (Peters et al., 2020; Smith et al., 2021). No previous reviews exist which have focused comprehensively on all studies applying the principles of the social ecological approach without limits to the field of research. Moreover, this review identified existing gaps in the use of different ecological levels measuring the physical environment in relation to physical activity. Previous reviews on social ecological approaches exist (Golden and Earp, 2012; Kok et al., 2008; Richard et al., 2011), but no recent review has applied a systematic search and identification of literature on this topic.

There were limitations in this review that should also be considered. This review took a general level approach to systematically map the methodological aspects applied in capturing the spatialities of physical activities in the studies using a social ecological approach. Thus, in choosing this approach, the review did not report the observed results between the physical environment and physical activity. Furthermore, the reliability and validity of the outcome measures were not systematically examined. We did not systematically analyze the study design issues such as the sample size and representativeness of the studies. Furthermore, the categorization of different levels of the social ecological approach used in the studies included in this review was based on one particular socio-ecological model (Sallis et al., 2006). We recognize that other models of the social ecological approach (Kok et al., 2008; Richard et al., 1996) differ slightly from the model used here. Because this review focused particularly on the physical environment in relation to physical activity, it did not report studies applying the social ecological approach that have not included the physical environmental aspects. Related to this aspect, search words of "school" and "workplace" were left out. This decision was made after an initial search word analysis and selection. Most of these studies were irrelevant for the purpose of this review because they focused on non-relevant settings (e.

g., indoor school or workplace environments), or on interventions on the social environment in workplace or school settings. Thus, most of these studies did not include any elements of the outdoor physical environment that could be modeled with different spatial approaches. It should be also noted that the grey literature on the topic was not included in this review which might be seen as a limitation (Gebel et al., 2015).

5. Conclusions

Current physical activity research applying social ecological models of health behavior relies on simplistic conceptualizations of the spatial context and methods to measure spatialities of physical activity behavior. There are multiple approaches that could be applied in studies measuring the physical environment in relation to physical activity that can help the field in moving forward from the notions of contextual influences that rely solely on immediate home surroundings. Given the identified gaps in the literature, studies that measure the physical environment objectively with methods that capture the environmental exposure beyond home locations and combine this information with multiple levels of the social ecological approach simultaneously are needed to understand how factors of the physical, intrapersonal, sociocultural, natural, information, and policy levels together affect physical activity behavior.

Ethics approval and consent to participate

Not Applicable.

Consent for publication

Not Applicable.

Availability of data and material

The datasets generated and analyzed during the current study are available in the Zenodo repository (10.5281/zenodo.5184745).

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Authors' contributions

TR, AK, MaS, MK contributed to the conception and design of the work; TR, AK, MaS, PB, AJP, MK contributed to the acquisition and analysis of the data; TR, AK, PB, AJP, MK contributed to the interpretation of data; all authors contributed to drafting the work and substantively revised it during the writing process.

Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.healthplace.2021.102737.

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